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FACIES CONTROL ON THE COMPOSITION OF SERPUKHOVIAN AND EARLY BASHKIRIAN FORAMINIFERAL ASSEMBLAGES IN THE MIDDLE TIEN-SHAN MOUNTAINS, CENTRAL ASIA

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Abstract. Serpukhovian-lower Bashkirian deposits are widely developed in the Middle Tien-Shan Mountains of Uzbekistan and adjacent countries of Central Asia. These deposits formed in a sedimentary basin exhibiting four distinctive facies that differ in foraminiferal diversity and population density. The facies types, named for mountain ranges containing representative sections, are called 1) Talassic, for inner shelf, shallow- water marine carbonates; 2) Ugamic, for carbonaceous deposits accumulating on an open, shallow-water, outer carbonate shelf platform; 3) Karzhantauic, for interbedded volcaniclastics and shallow-water marine carbonates deposited on a eroded surface; and 4) Paltauic, for basinal beds containing thin-bedded, graded and laminated organic limestones and interbedded turbidites. A statistical program (Sorenson's Coefficients of Species Similarity) was used to compare assemblages in eight foraminiferal zones from coeval fades across the basin. Highest similarity coefficients occur in the early Serpukhovian and are probably related to a marine transgression that flooded the basin. Regression and volcaniclastic sedimentation account for lower coefficients in the remainder of the Serpukhovian. Increased foraminiferal diversity and abundance in the earliest Bashkirian were probably caused by the opening of new connections to adjacent Paleotethyan basins only to be followed by more restricted environmental conditions and lower similarity coefficients later in the early Bashkirian.

Riassunto. Successioni di età Serpukhoviana-Bashkiriana inferiore sono molto diffuse nelle montagne del Tien-Shan centrale in Uzbekistan e nelle regioni adiacenti dell'Asia centrale. Esse si sono formate in un bacino sedimentario in cui è possibile individuare quattro associazioni di facies sulla base della diversità nei foraminiferi e la densità delle loro popolazioni. Le associazioni di otto zone a foraminiferi sono state confrontate tra di loro mediante un programma statistico (coefficiente di similarità specifica di Sorenson). Le maggiori similarità si trovano nel Serpukhoviano inferiore e sono probabilmente collegate alla trasgressione marina che interessò il bacino. La successiva regressione e sedimentazione vulcanoclastica spiegano le basse similarità per il resto del Serpukhoviano. La ripresa della diversità ed abbondanza in foraminiferi nel successivo Bashkiriano basale furono probabilmente dovute all'apertura di nuove connessioni con l'adiacente Paleotetide. Tuttavia già durante il Bashkiriano inferiore condizioni più confinate produssero più bassi coefficienti di similarità.

Introduction

Serpukhovian - lower Bashkirian deposits are widely developed in the Middle Tien-Shan of Uzbekistan and adjacent countries (Fig. 1). They are part of a continuous marine carbonate sequence, over 1200-m thick that was formed in different areas on a carbonate shelf in Serpukhovian - early Bashkirian time. Regional stratotypes (type sections) of the Lower Carboniferous and the lower Bashkirian are concentrated in the western part of mountain ranges between the Chatkal and Talass Alatau mountains, including the Mashatian, Keltimashatian and Koikebiltaustian substages of the Serpukhovian and the Seslavian and Uzunbulakian substages of the lower Bashkirian (Fig. 2). The foraminiferal assemblage zones, established for these substages (Orlova 1994; Orlov-Labkovsky 1999), are correlated with Urals-Russian Platform foraminiferal zones in Table 1.

Basin from the Chatkal to Talass Alatau ranges and in the Karzhantau Range exposes four distinct facies types. These are the Talassic (shallow-water carbonate sediments), Ugamic (an open shallow sea accumulation of carbonaceous sediments), Karzhantauic (a volcanogenic – terrigenous shelf sequence with interbedded shallow-water carbonates) and Paltauic (carbonaceous – terrigenous sediments of the basin) facies-types of sections. The foraminifers in each facies differ in species and generic diversity and density of populations.

Materials and method

The means used to correlate facies to foraminiferal associations include determining the characteristic or dominant species, and the areal distribution of the fauna

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Euroasiatic Scheme in Urals and Russian Platform (Kagarmonov & Donakova 1990)				Stratigraphical Scheme in the Middle Tien-Shan (Orlova, 1994, 1995)				
System	Stage	Ammonoid Zones	Foraminifer Zones	Substage	Brachiopods	Foraminifers	Conodonts	Ammonoids
					Sergunkova (1989) Tulyandina (per. comm. 1989)	Orlova (1994, 1995) Orlov-Labkovsky (1999, 2001)	Nemirovskaya & Nigmadzanov (1994); Bensh et al.(1998)	Nikolaeva & Nigmadzanov (1991)
CARBONIFEROUS	LOWER BASHKIRIAN	*Bilinguites - Cancelloceras*	*Pseud. praegorskyi*	Uzunbulakian	*Choristites bisulcatiformis – Choristites kshemischensis – Meekella eximia*	*Pseudostaffella praegorskyi*	*Idiognathodus sinuosus*	*Bilinguites - Cancelloceras*
			Pseudostaffella antiqua			*Pseudostaffella antiqua*		
		Reticuloceras - Bashkortoceras	*Plect. varv. - E. pseudosir. - E. postmosquen.*	Seslavian	*Spirifer bisulcatus – Productus productiformis*	*Plectostaffella longiscula– Plectostaffella rotunda*	*D. noduliferus – Id. corrugatus*	*Reticuloceras - Bashkortoceras*
		Homoceras - Hudsonoceras	*Plectostaffella bogdanovkensis*			*Plectostaffella jakhensis – Plectostaffella varvariensis*	*Declinognathodus* *D. noduliferus*	*Homoceras* *Homoceras*
								Is.ventricosum
							D. praenoduliferus	*Is.subglobosum*
	SERPUKHOVIAN	*Fayettevillea – Delepinoceras*	*Eostaffellina protvae – Eosigmoilina explicata- Monotaxinoides subplana*	Koikebiltauian	*Beleutella magna*	*Plectostaffella karsaklensis*	*G. postbilineatus*	*Fayettevillea– Delepinoceras*
						Plectostaffella mira obtusa – Eostaffella turkestanica	*Gnathodus bilineatus bollandensis*	
				Keltemashatian	*Striatifera angusta*	*Eosigmoilina explicata – Loeblichia minima - Plectostaffella. primitiva*		
		Pseudoendot. globosa – N. parvus		Mashatian	*Latiproductus rectestrius*	*Neoarchaediscus regularis – Biseriella parva*		
	VISEAN	*Hyperg.-Fergan.*	*Endothyranopsis crassa*		*Gigantoproductus giganteus*	*Endothyranopsis crassa*	*Paragnathodus nodosus*	*Hypergoniatites – Ferganoceras*

Tab. 1 - Comparison of Serpukhovian and Bashkirian faunal zones between the Middle Tien-Shan and Urals - Russian Platform (modified after Orlova 1994, 1995).

and its ecological features (Rauzer-Chernousova 1960, 1967; Fomina 1969).

The database consists of 1663 specimens (303 species). In order to evaluate the similarity of foraminiferal associations within the same facies or between different facies for each foraminiferal zone, we used quantitative Sorenson's Coefficients of Species Similarity - CSS (Odum 1971; Southwood 1978). Among the ten studied sections, five were representative; therefore, the coefficients were calculated only for these sections: Koikebiltau and Mashat (Talassic FT), Akkuiluk (Ugamic FT), Uya - 60/7 (Karzhantauic FT) and Paltau (Paltauic FT) (Fig. 2).

The Sorenson's Coefficients of Species Similarity is calculated with the following formula:

$$CSS = 2C / (A + B)$$

where "C" is the number of species common to two sections in a foraminiferal zone, and "A" and "B" are the total number of species in each section within the foraminiferal zone.

This index is designed to equal 1 (or 100%) in cases of complete faunal similarity and 0 (or 0%) if the sites have no species in common. One of the great advantages of this method is its simplicity. The index is particularly useful for evaluating the similarity of two species lists (Magurran 1988). It has been applied, for example, in analysis of the biogeography of Devonian rugose corals (Naimark et al. 1998), and of the paleobiogeographic affiliation of Carboniferous faunas of the Qaidam Basin, China (Li & Zhang 1999).

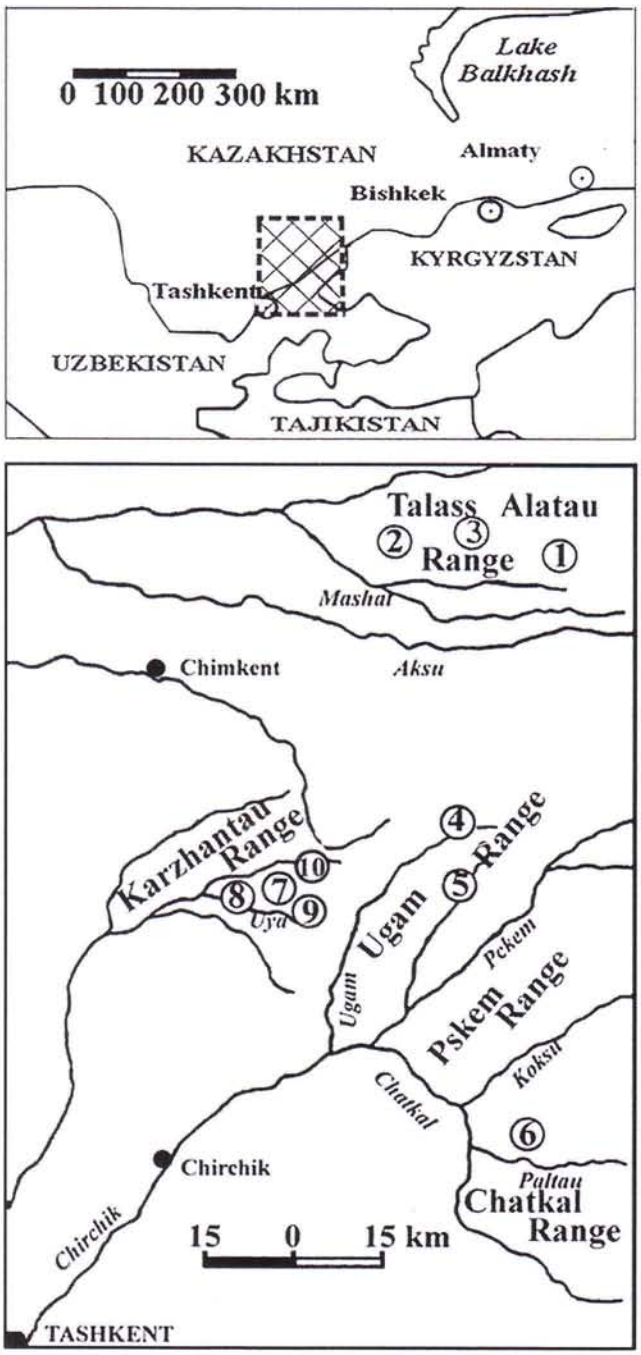

Fig. 1 - Location of studied Serpukhovian/Bashkirian sections, Middle Tien-Shan: Talassic FT: 1 – Mashat, 2 – Koikebiltau, 3 – Djianisusai; Ugamic FT: 4 – Akkuiluk, 5 – Yakhak; Paltauic FT: 6. Paltau; Karzhantavic FT: 7 – River Uya - 60/7, 8 - River Uya - 64/8, 9 - River Uya – 69/9, 10 - River Djegirgen. FT – facies types.

Facies types

Marine sedimentation began around the Devonian – Carboniferous boundary in Middle Tien-Shan and persisted into the Serpukhovian and early Bashkirian (Fig. 3). Differences in lithological sequences testify to differences in topographic relief, tectonic movements and sedimentation within the basin (Osipova et. al. 1971; Fomina 1969).

Talassic type

The Talassic type contains shallow-water carbonate sediments from an inner marine shelf (Koikebiltau and Mashat sections). The Serpukhovian interval is characterized by high-energy, near-shore to offshore facies, consisting of light gray, thick-bedded, ooid, crinoidal, algal - foraminiferal and brachiopodal limestone banks. These beds formed shoals.

During the early Bashkirian near-shore, moderately agitated shallow- water environments prevailed, forming gray, bedded, fine-grained and nodular limestone to ooid, algal - foraminiferal limestone

Chert concretions abound at the top of sequence. Foraminifers such as *Endothyranopsis, Omphalotis, Globoendothyra, Forshia, Eostaffella (Ikensieformis)* and others represent eurobiontic and stenobiontic populations. The most diverse and highest density populations are observed in this facies.

Ugamic type

The Ugamic type is open, shallow marine carbonate sediment and represents accumulation on an outer carbonate shelf platform (Akkuiluk and Yakhak sections). The carbonates are typically gray, bedded, fine-grained limestone.

Continuous sedimentation and a relatively constant stratal thickness characterize the sequence. Shoal and intershoal sediments as well as up to 1 m thick lenses of calcareous breccia also occur. Chert, both concretions and bedded, appears in the middle part of the section. Fossils include conodonts and foraminifers as well as rare brachiopods.

The foraminiferal association is characterized by a gradual increase in diversity during the Serpukhovian and into the lower Bashkirian. The high species diversity of the foraminifers contrasts with the low abundance of specimens except in offshore, shallow-water shoals that have high population density and species diversity. The population density increases from the bottom to the top of the sequence.

Karzhantauic type

The Karzhantauic type is a volcaniclastic and shallow marine carbonate sequence, deposited in the Karzhantau Range (Uya and Djegirgen River Basins). Serpukhovian strata consist of massive-bedded tuffaceous conglomerate and tuffaceous sandstone which are replaced westward by finer-grained terrigenous and detrital limestone. Continuous beds of limestone occur at the top. Foraminiferal diversity and abundance are high.

Bashkirian, tuffaceous sandstone passes to the west into detrital foraminiferal limestone and interstratified tuff to the east. Upward, strata of trachytic tuffaceous conglomerate, foraminiferal sandstone and fossiliferous sandy limestone occur. The foraminifers have low diversity, but a high population density.

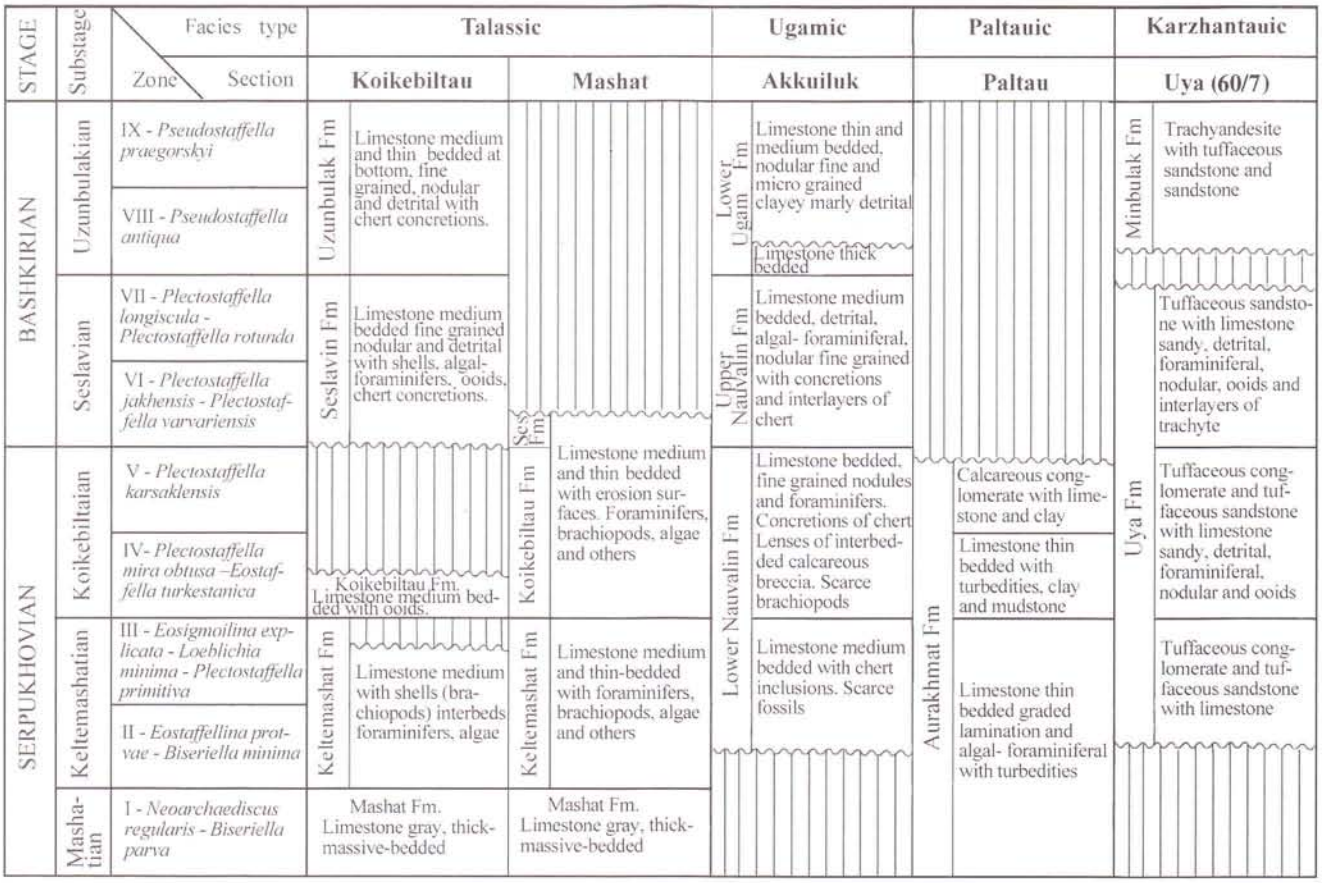

Fig. 2 - Correlation chart of the main sections for the various facies and formations in the Serpukhovian / Bashkirian sections in the Middle Tien-Shan.

Paltauic type

The Paltauic type includes basinal carbonaceous-terrigenous sediments, characterized by thin-bedded, graded and laminated organic limestone with turbidite interbeds (Paltau section). The limestone contains admixtures of sand and clay in the middle of the section. The sequence terminates with a limestone conglomerate and calcareous shale. The foraminiferal assemblage is characterized by a gradual but insignificant increase in diversity and has a moderate population density. Foraminifers include *Biseriella parva* (N.Tchernysheva), *Neoarchaediscus regularis* (Suleimanov) and *Monotaxinoides priscus* (Brazhnikova & Yarzeva). Some species, such as *Omphalotis omphalota* (Rauzer-Chernousova & Reitlinger) and *Eostaffella ikensis* Vissarionova have thick shells and show traces of transportation. They appear in the late Visean, but disappear in the early Serpukhovian. Other fossils, such as conodonts, ammonoids, algae (*Koninkopora*) and brachiopods are also present but not abundant.

Facies associations and similarity of foraminiferal zones

Serpukhovian - lower Bashkirian foraminifers are moderately to highly abundant and highly diverse (from 40 to 160 species) depending on depositional environments within the basins. Assemblages within foraminiferal zones I – VIII (Fig. 3) show a gradual change in eostaffellid species and genera and other taxa. The number of species and genera found from the late Visean is sharply reduced. The Serpukhovian is characterized not only by the evolution of the family Eostaffellidae, but also by the appearance of small foraminiferal genera such as *Rectoendothyra, Biseriella, Globivalvulina, Monotaxinoides*, representatives of the family Asteroarchaediscidae and others.

The Sorenson's Coefficients of Species Similarity (CSS) values for foraminiferal zones I-VIII are presented in Table 2. They are based on comparisons between sections in the same facies (KM in Table 2) and from different facies (KA through PU in Table 2).

In order to interpret the significance of the coefficient values, I separated them into five categories (Fig. 4): highest CSS at 85 -100 %; high CSS at 70 -85 %; moderately high at 55-70 %, moderate at 40- 55 % and low at 25 -40%. The highest CSS records are from zones I (75% of total records) and II (25%); the high CSS are from zones II (20%), III (10%), IV (10%), VI (30%) and VII (30%); the moderately high CSS are from zones III

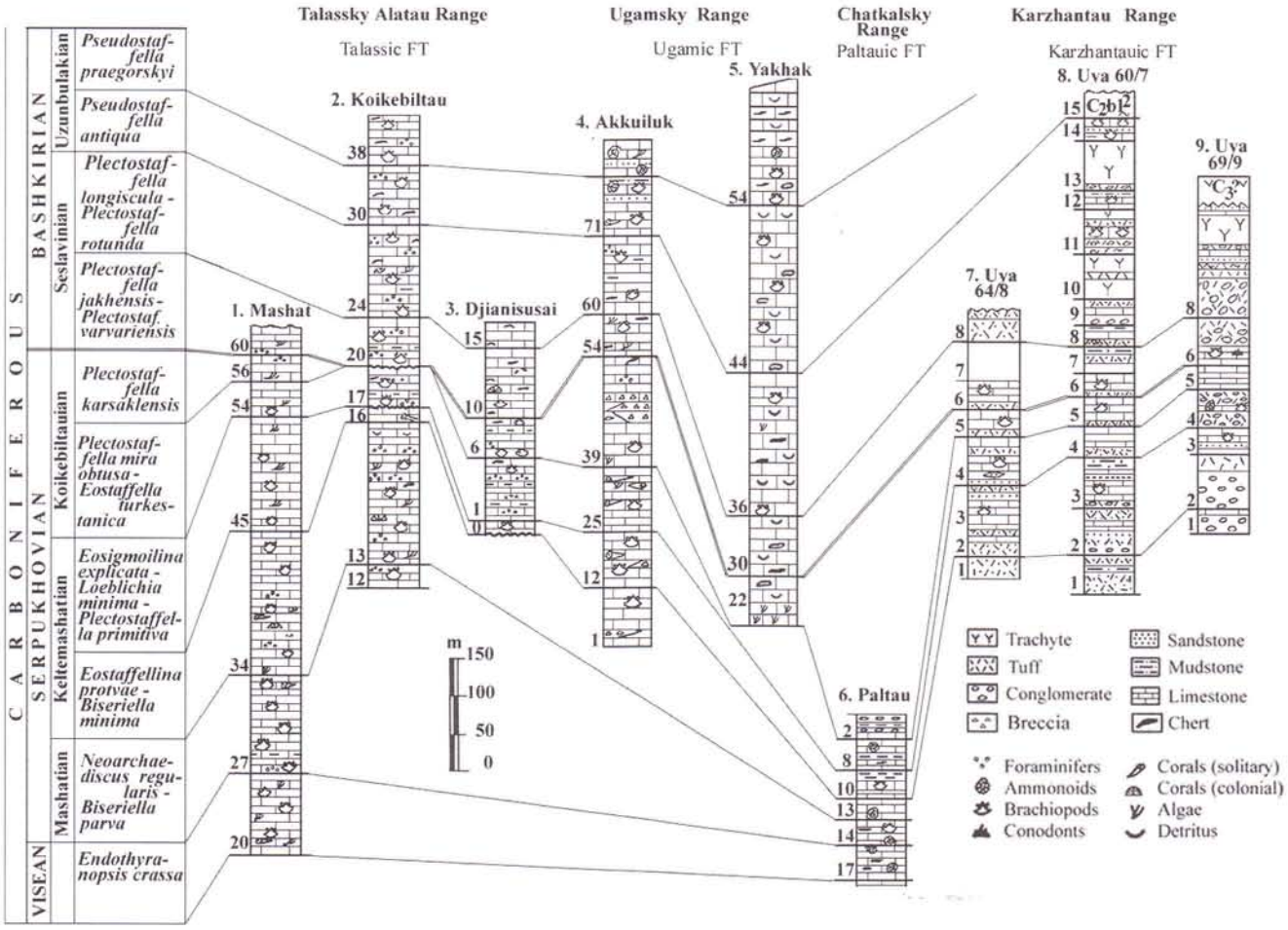

Fig. 3 - Correlation of Middle Tien-Shan sections (modified after Orlova 1995).

(35%), IV (35%), V (15%) and VI (15%); the moderate CSS are from zones III (29%), IV (29 %) and V (42%); the low CSS is from zone VIII (100%).

Most of the CSS records vary within the high (10 records or 23.8%) and moderately high (20 records or 47.6%) categories. The seven moderate CSS records composed 6.6%. Among them two records belong to foraminiferal Zone III, two records to Zone IV and three to Zone V. For Zone III the similarity is between the Paltau and Uya sections at 52.74% and the Mashat and Uya sections at 52.17%. For Zone IV the similarity, is between the Koikebiltau and Mashat sections (CSS-53.33%) and Mashat - Akkuiluk (CSS- 52.17%) and for Zone V between Mashat and Paltau (CSS - 42.71%), Akkuiluk - Paltau (54.68%) and Paltau – Uya (48.27%). The lowest category includes only one record (2.4%) between the Koikebiltau and Akkuiluk sections within Zone VIII (27.90%).

Discussion

Based on my data it is possible to construct the following developmental history for the Serpukhovian - lower Bashkirian interval in the Middle Tien-Shan basin. The highest species similarity is found in foraminiferal zones I and II independent of their facies differences. The high faunal similarity probably is related to a rapid marine transgression in the early Serpukhovian (Sergunkova 1989). Similarities between species assemblages in zones III, IV and V zones are lower (mostly between 55-70%) probable because of a regression during the remainder of the Serpukhovian (Table 2). Relatively low similarities in the Zone III (52.74% and 52.17%) correspond to the Karzhantauic facies represented by volcanic-clastic strata with rare shallow marine sediments. The low similarities in the Zone IV (53.33% and 52.17%) correspond to basin shoaling and shoreline fluctuation in the Talassic facies. The low similarities in the Zone V (42.71%, 48.27% and 54.68%) correspond to the Paltauic facies related to the closing of the basin.

The final phase of basin development during the early Bashkirian records an increase in species and similarity of the faunas. The increase is probably related to connections opening between different marine basins and

Zone	KM	KA	KP	KU	MA	MP	MU	AP	AU	PU
I	94.1		88.8			86.59				
II	86.48		77.87			80.76				
III	71.18	61.66	56.4	68.75	58.62	55.93	52.17	64.34	55.32	52.74
IV	53.33	55.46	63.06	55.76	48.35	74.69	63.16	57.14	61.85	61.85
V					66.05	42.71	68.04	54.68	67.21	48.27
VI	61.11	77.33		76.19	60.71		58.71		75.49	
VII		73.14		76.19					79.75	
VIII		27.9								

Tab. 2 - Sorenson's Coefficients of Species Similarity (CSS) in percentages between two sections on each foraminiferal zone: KM = Koikelbitau – Mashat, KA = Koikelbitau – Akkuiluk, KP = Koikelbitau – Paltau, KU = Koikelbitau – Uya, MA =Mashat – Akkuiluk, MP = Mashat - Paltau, MU = Mashat – Uya, AP = Akkuiluk – Paltau, AU = Akkuiluk- Uya, PU = Paltau – Uya. Only KM compares sections within the same facies.

the reduction of contrasts of environmental conditions. Zone VI has relatively high and moderately high similarities (55 -85 %) and Zone VII has relatively high similarities (70-85 %) in different facies

Foraminiferal Zone VIII occurs in the Koikebiltau (Talassic facies) and Akkuiluk sections (Ugamic facies). The CSS for this zone show a low rate of species similarity (27.90 %). A possible reason for these results is that at Akkuiluk foraminifers are abundant and diverse only in the bottom of the section. Upward the assemblage is represented only by scarce eurybiontic species. The similarity in this zone is caused by species common to the different facies. These include: *Pseudostaffella antiqua* (Dutkevich), *P. paracompressa* Safonova, *P. composita* Grozdilova & Lebedeva, *Semistaffella variabilis* (Reitlinger), *S. varsonoviefae* (Rauzer-Chernousova), *Millerella elegantula* Rauzer-Chernousova, *M. carbonica* Grozdilova & Lebedeva, *Ozawainella aurora* Grozdilova & Lebedeva, and *O. umbonata* Potievskaya.

The diversity of species and genera increases from the beginning of the Serpukhovian and attains a maximum in the early Bashkirian within Zone VII.

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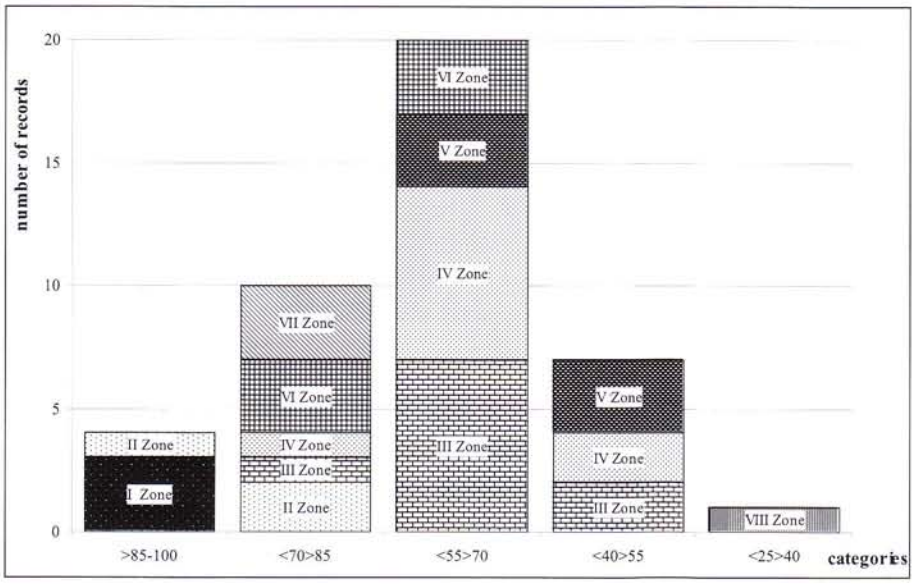

Fig. 4 - Distribution of Sorenson's Coefficients of Species Similarity. Number of records from Table 2 are grouped in 5 categories by foraminiferal zones: I - *Neoarchaediscus regularis - Biseriella parva*; II - *Eostaffellina protvae - Biseriella minima*; III - *Eosigmoilina explicata - Loeblichia minima - Plectostaffella primitiva*; IV- *Plectostaffella mira obtusa –Eostaffella turkestanica*; V - *Plectostaffella karsaklensis*; VI - *Plectostaffella jakhensis - Plectostaffella variensis*; VII - *Plectostaffella longiscula - Plectostaffella rotunda*; VIII - *Pseudostaffella antiqua*.

REFERENCES

Bensh F.R., Nigmadzanov I.M. & Iskandarkhodgaev T.A. (1998) - Stratigraphy of the Middle Tien-Shan. In: *Geology and Useful Minerals of Uzbekistan. Nauka (FAN)*: 95 -123. Tashkent (in Russian).

Fomina E.V. (1969) - The peculiarities of assemblages of foraminifers in varied facial deposits in Tarussian and Steshevian seas of Moscovian Syncline. *Voprosii Micropaleontologii*, 11: 18–34, Moskva (in Russian).

Kagarmonov A. Kh. & Donakova L.M. (eds.) (1990) – Kamaeniugolnaya sistema (Carboniferous System). In: *Reshenija Mezhvedomstvennogo regionalnogo stratigraphicgeskogo soveshanija po srednemu i verhnemu paleozou Russkoi Platformi (Leningrad, 1988)*. 95 pp., Leningrad (in Russian).

Li Shou Jun & Zhang Hong. (1999) - Paleobiogeographic affiliation of Carboniferous faunas of the Qaidam Basin, China. *Acta Micropal. Sinica*, 16 (2), 181-189, Nanking (in Chinese with English abstract).

Magurran A.E. (1988) - Ecological diversity and its measurement. *Princeton University Press*, New Jersey: 114 p., Princeton.

Naimark E.B., Ulitina L.M. & Markov A. V. (1998) - Quantitative analysis of the biogeography of Devonian rugoses. *Paleontol. Zhurnal*. (6): 16-23, Moskva (in Russian).

Nemirovskaya T.I. & Nigmadzanov I.M. (1994) - The Mid-Carboniferous event. *Cour. Forsch. Inst. Senckenberg*, 68: 319–335, Frankfurt.

Nikolaeva S.V. & Nigmadzanov I.M. (1991) - New data about the age of the Khodzhirbulakskoj suite in connection with problems of the Lower and Middle Carboniferous boundary. *Bul. Moskovskogo obshestva ispitatelei prirody*. Otd. geol., t.65, n.1: 128, Moskva. (in Russian)

Odum E. P. (1971) - Fundamentals of Ecology. W.B. Saunders Company. 574 pp., Philadelphia.

Orlova O.B. (1994) - The Serpukhovian and Bashkirian Stages of the Middle Tien-Shan. *Recent data on the Paleozoic biostratigraphy of the Russian platform and folded areas of the Urals and Tien-Shan*. VNIGNI: 58-59, Moskva (in Russian).

Orlova O.B. (1995) - Stratigraphy and Foraminifera of marginal deposits of the Lower and Middle Carboniferous of a western part of the Chatkal-Talass Mountain system. Summary of Ph D. *Tashkent State University*. 28 pp., Tashkent. (in Russian with English abstract).

Orlov- Labkovsky O. (1999) - The Serpukhovian Stage in the Middle Tien-Shan Mountains (Uzbekistan and adjacent countries). *Abstract. XIV Intern. Congr. Carbon. Permian,*: 107, Calgary.

Orlov- Labkovsky O. (2001) - The Serpukhovian Stage in the Middle Tien-Shan Mountains (Uzbekistan and adjacent countries). In L. V. Hills, C.M. Henderson, & E.W. Bamber (Eds.) - Carboniferous and Permian of the World. *XIV Intern. Congr. Carbon. Permian. Mem.* 19: 796-801, Calgary.

Osipova A.I., Hecker R.Th. & Belskaya T.N. (1971) – Peculiarities of distribution and changes of fauna in Late Visean and Early Namurian epicontinental seas of the Russian platform. *Trudii Paleonologicheskogo Instituta. 130. Izdatelstvo Akademii Nauk*: 279–293, Moskva (in Russian).

Rauzer-Chernousova D.M. (1960) - The criterion of the geographical area in the systematics of Foraminifera. *Prequaternary micropal.* Problem 6: 23-31, Moskva (in Russian).

Rauzer-Chernousova D.M. (1967) - About zones of common and regional stratigraphical scales. *Izvestiya AN SSSR, Geologiya*, 7: 104 – 118, Moskva (in Russian).

Sergunkova O.I. (1989) - Cyclicity of the sedimentary accumulation of the Lower Carboniferous in the Chatkal -Talass Basin in the Middle Tien-Shan (based on the analysis of brachiopods). In: *Biostratigraphycal Researches in Uzbekistan*: 4-17 pp., Tashkent (in Russian)

Southwood T.R.E. (1978) - Ecological methods. Chapman & Hall. A Halsted Press. 524 pp., London.